National Aeronautics and Space Administration

Capture Mechanism and Capture Process

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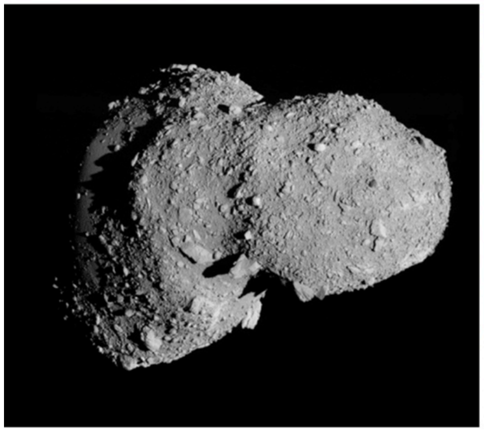
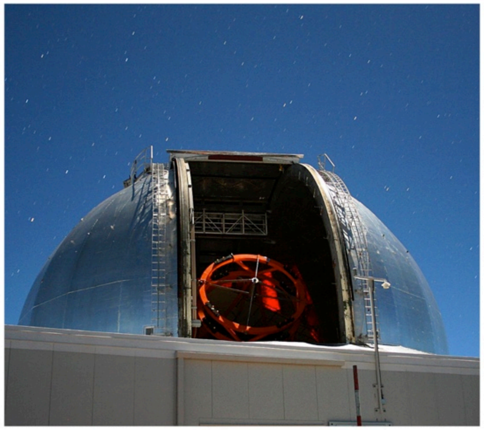
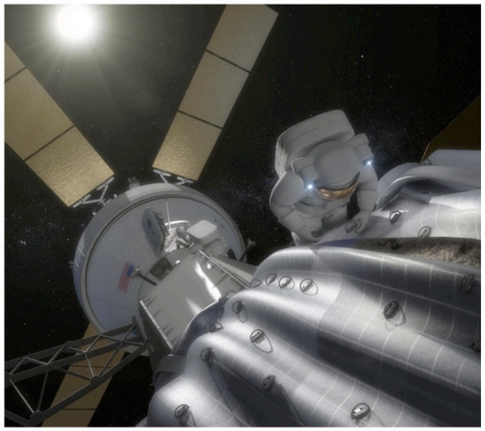





Key Characteristics of Asteroid for Capture

Composition/ Strength

- Rock (>>1PSI)
- Dirt Clod (~1PSI)
- Rubble Pile(<<1PSI)

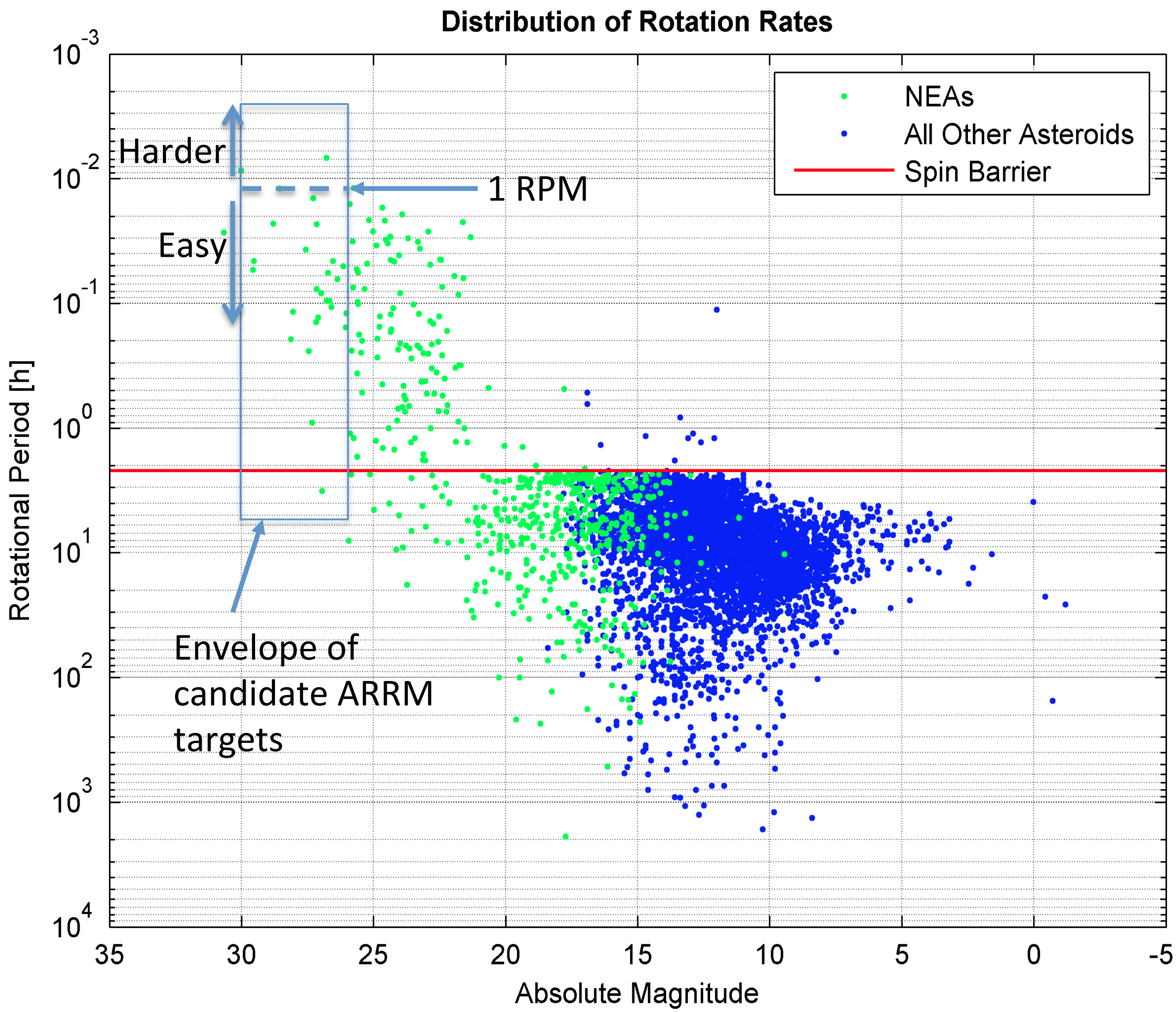
Spin State

- Slow (<<1RPM), Simple Spin
- Slow (<<1RPM), Tumbling
- Fast (~>1RPM), Simple Spin
- Fast (~>1RPM), Tumbling

- For capture, the primary concerns are composition/strength and spin state
- Have been evaluating passive and active control options that limit forces on the spacecraft/solar arrays to <0.1 g peak for the fast/tumbling state

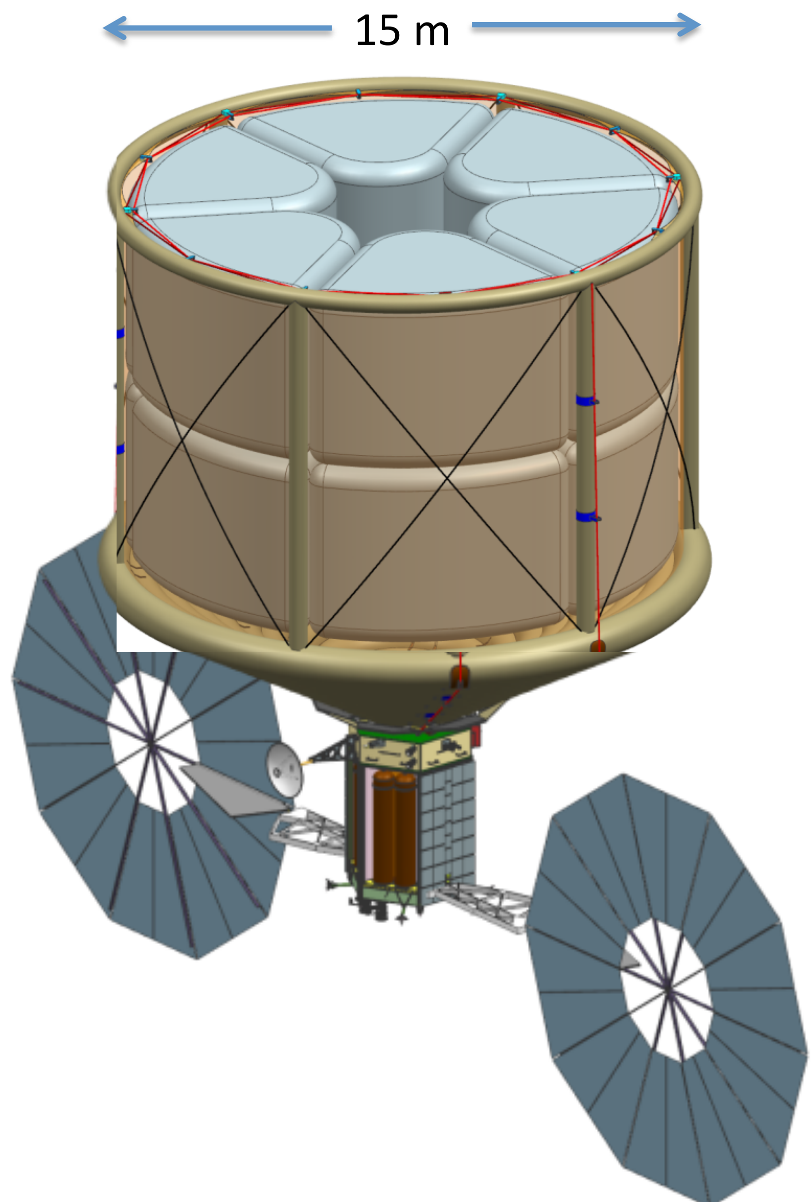
Spin Periods of Near-Earth Asteroids

- Many small NEAs spin faster than the rubble pile spin barrier, but may be "dirt clods“
- Worst case assumed to be 5-13 m diameter NEA with a spin rate of 2 RPM and tumbling

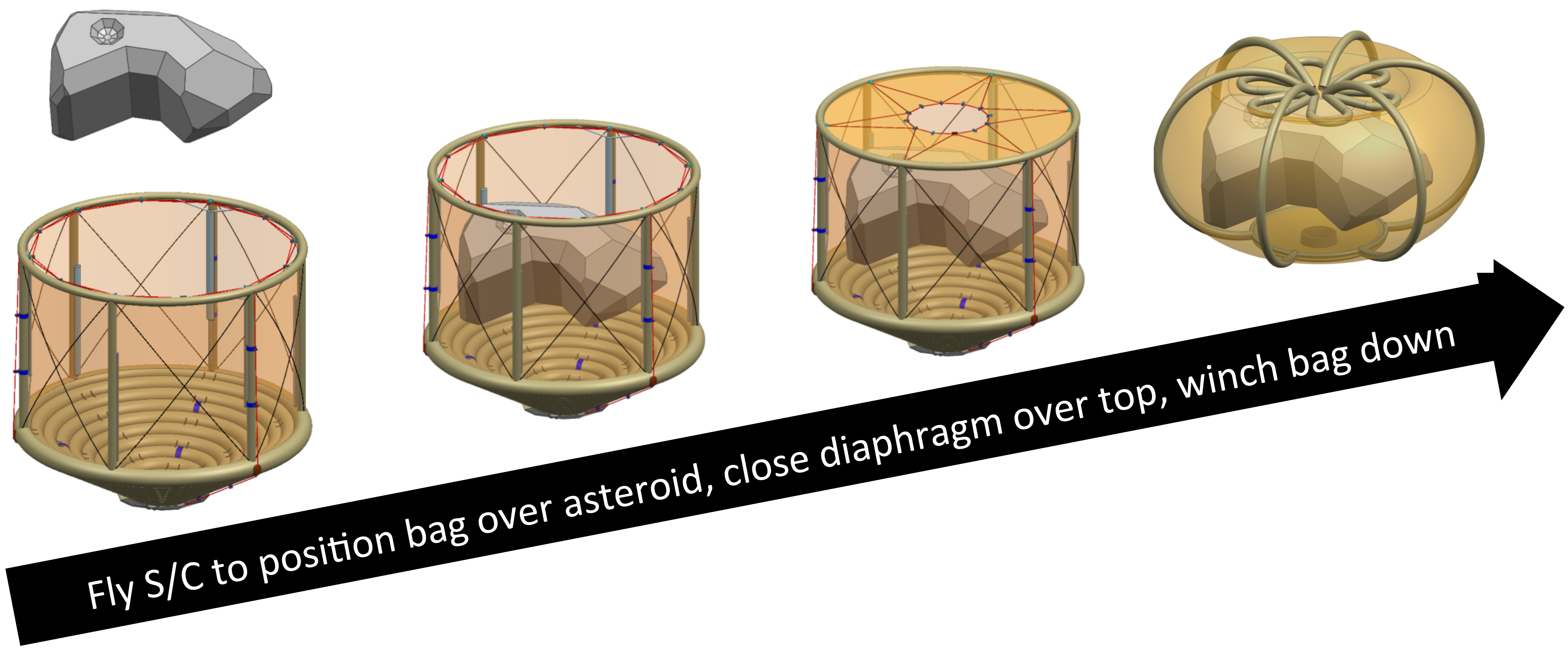


Capture Mechanism Concept

- Capture bag formed of cylindrical barrel section and conical section attached to S/C
- Inflatable exoskeleton to deploy bag after arrival at asteroid
- Circumferential cinch winches close diaphragm at top of cylindrical section and confine asteroid after deflation
- For fast-spinner, air bags quickly immobilize bag in asteroid frame at very low contact pressure (<<1 PSI)
- Circumferential and axial cinch winches control motion, retract bag, and position asteroid center-of-mass.

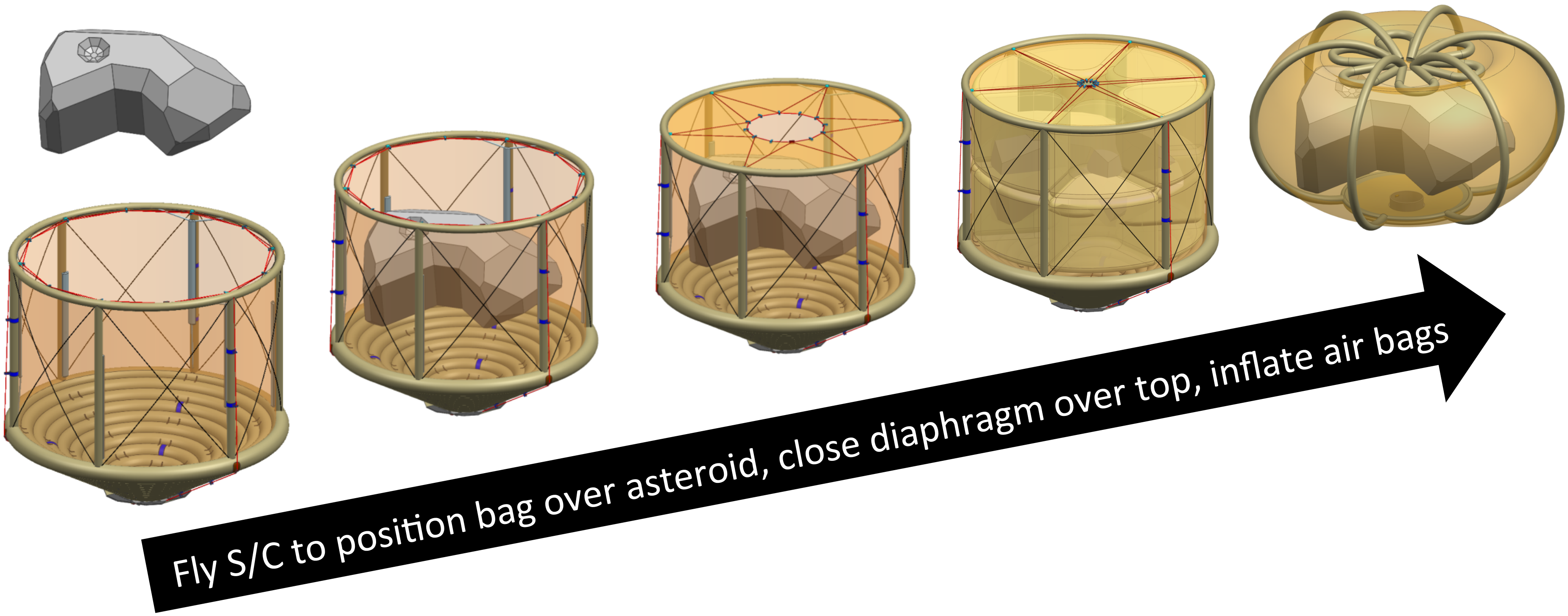


Slow Spinner Capture Sequence



- S/C approaches, no need to match rotation state (upper bound of spin rate for this mode has not been determined)
- When asteroid is centered in the bag, close top diaphragm, begin controlled winching process, cinch asteroid tight to S/C while venting.

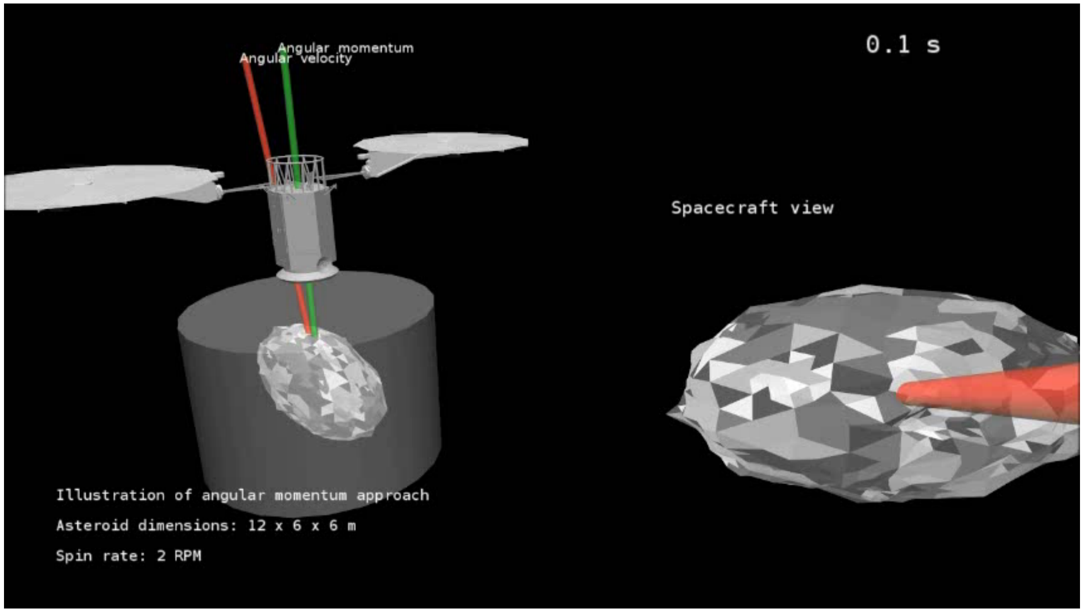
Fast Spinner Capture Sequence



- S/C approaches and matches spin along projected asteroid spin vector a short time in the future.
- When asteroid is centered in the bag, close top diaphragm, and at the moment spin is matched, inflate air bags w/pressure <<1 PSI to limit loads on surface of asteroid, achieving controlled capture quickly; cinch asteroid tight to S/C while venting.
- Mechanism provides elasticity to control loads to solar arrays .

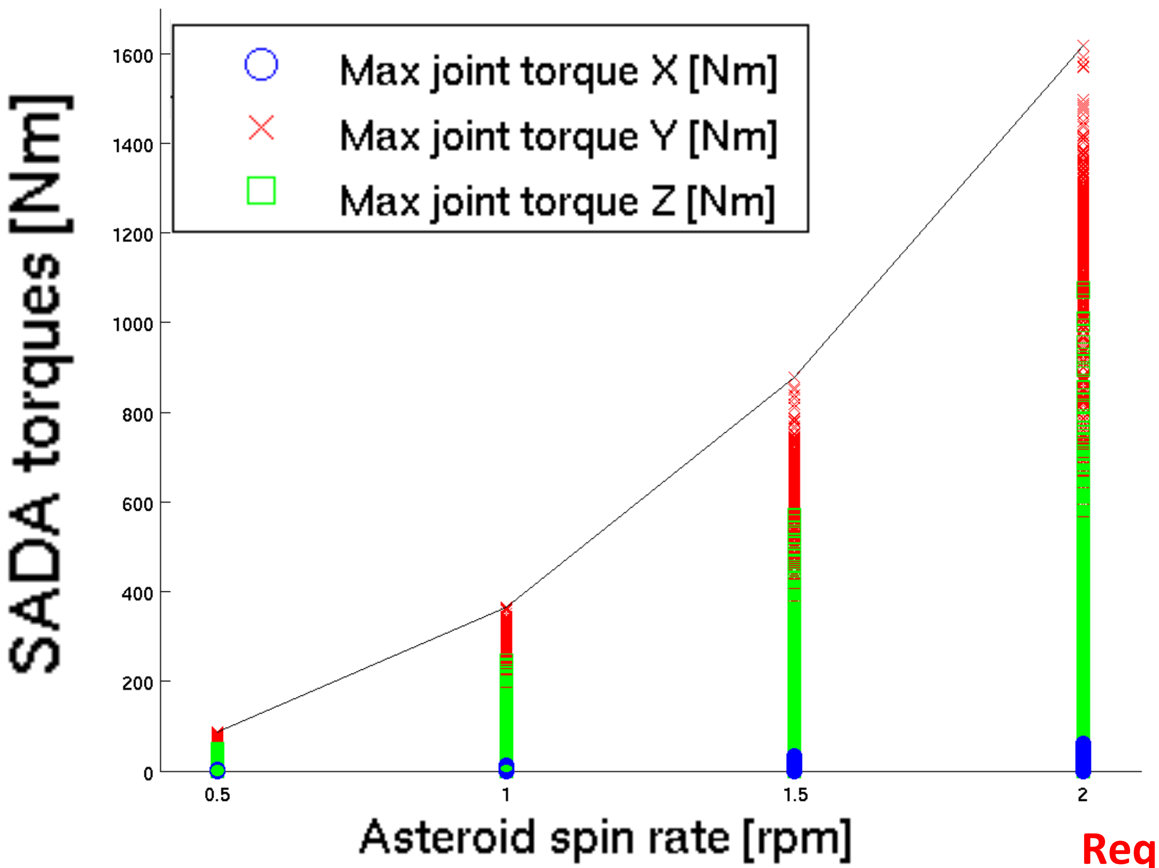
Passive Capture, Matched Instantaneous Spin Vector

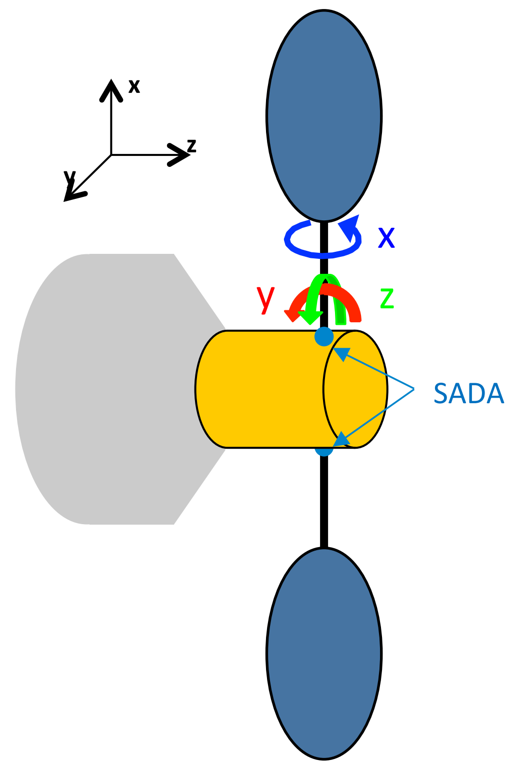
- Asteroid inertial and spin properties determined by observation and state accurately projected into the future by many minutes to hours
- Asteroid instantaneous spin vector circulates around angular momentum vector
- Spinning S/C approaches along projected instantaneous spin vector and grabs when vector matches S/C location to minimize bag scuffing



Monte Carlo Simulation Results

- 5,472 samples (4 spin rates, 36 shapes, and 38 fully nutated states)
- Grab uses optimized generalized 6-DOF spring-loaded joint
- Spring parameters are derived from an optimization within the base-line toroidal isolation device design constraints





Requirement: ≤1,765 Nm

SADA = Solar Array Deployment Actuator (the limiting component for S/C acceleration)

Capture Testbed

- Initial 1/5 scale capture testbed has inflatable exoskeleton with winches suspended from gantry over asteroid on end of 8-DOF robot arm that can spin and tumble the asteroid in the S/C (lab) reference frame.
- Force-torque sensor at attachment of asteroid to arm allows realistic spin physics.
- Questions that will be answered by scale model and full scale testing (not likely answerable by physics-based simulation) include:
  - Cinch cords behavior and control of bag fabric, demonstrating full closure of the bag?
  - Characterizing snagging of the bag by the asteroid, forces on the bag, and general control of the bag
  - Determining the best cinching and GN&C algorithms to manage the asteroid motion in the bag